inter-noise 2023
52nd International Congress and Exposition on Noise Control Engineering
"Quieter Society with Diversity & Inclusion"

The effects of ultrasound exposure with regard to the existing TLVs
a literature review

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Introduction

Noise is defined as any unwanted sound, and the health effects of noise have been well documented. Exposure to high levels of sound pressure can lead to hearing loss, tinnitus, and other health problems

Airborne ultrasound is used for various purposes both in industrial and public settings and is also often produced unintentionally by many sources

Ultrasound consists of mechanical (acoustic) waves, historically characterised at frequencies above the upper human audible limit

Many countries have included ultrasonic noise on the list of factors hazardous to health in the working environment. Even though the frequency range **above 20 kHz** has been studied, there is still not enough information regarding how it affects the human body

Introduction

The main sources of ultrasonic noise in the work environment are the so called low-frequency ultrasound process devices, such as **ultrasonic cleaners**, **ultrasonic welders**, ultrasonic erosion devices.

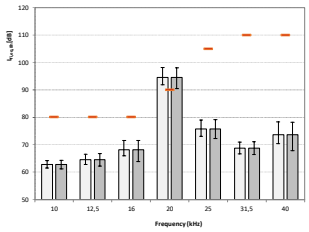
Introduction - TLVs

Frequency [kHz]	Sound pressure level [dB]											
	Japan	Russia (USSR)	Acton	USA (ACGIH)	England	Norway	Bulgaria	Canada	Australia	IRPA	Poland	Sweden
6,3	90							80				
8	90		75					80		80		
10	90		75	105				80	75	80	80	
12,5	90	80	75	105	75		75	80	75	80	80	
16	90	90	75	105	110		85	80	75	80	80	
20	**110**	**100**	**75**	**105**	**110**		**110**	**80**	**75**	**80**	**90**	**105**
25	**110**	**105**	**110**	**110**	**110**		**110**	**110**	**110**	**110**	**105**	**115**
31,5	**110**	**110**	**110**	**115**	**110**	**120**	**110**	**110**	**110**	**110**	**110**	**115**
40	**110**	**110**	**110**	**115**	**110**		**110**	**110**	**110**	**110**	**110**	**115**
50	**110**	**110**		**115**	**110**		**110**	**110**	**110**	**110**		**115**
63		**110**		**115**		**120**	**110**	**110**		**110**		**115**
80		**110**		**115**			**110**	**110**		**110**		**115**
100		**110**		**115**			**110**			**110**		**115**
125						**120**						**115**

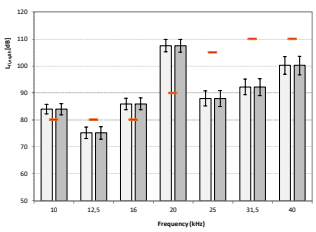
NOTE: Frequency in one-third-octave frequency bands

Introduction

Ultrasonic welder



Ultrasonic cleaner



TVLs (Poland)

Introduction - Instrumentation

In contrast to measurements of sound levels in the audible frequency range there are no **clearly defined instruments** intended to measure the sound pressure level in the **ultrasonic frequency range**

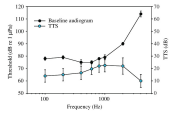
- **No international standards** for instruments and for measurments.
- **No requirements** for such instruments and methods of their periodic calibration as part of metrological control.
- Lack of fully assured measurement consistency at frequencies above 20 kHz.

Despite the lack of current international standards concerning ultrasonic noise measurements in the work environment, there is a possibility for adapting methods for the audible frequency range after taking account of several key measurement issues (eg. microphone)

EFFECTS OF ULTRASONIC NOISE ON HEARING

The results of environmental and laboratory studies in the 1960s showed that the temporary threshold shift (TTS) and the permanent threshold shift (PTS) of 0.25–10 kHz resulting from exposure to ultrasonic noise did not exceed 10–15 dB or was not observed at all if sound pressure level did not exceed 120 dB

Grigorieva V.M. 1965



NIHL at 13–17 kHz in workers exposed to ultrasonic noise over several years of work with cleaners and welding machines at level exceeding 80 dB

Grzesik J., Pluta E. 1986

TTS of 8–18 kHz resulted from a short-term exposure to signals of 17–37 kHz and intensity of 148–154 dB

Parrack H.O.1966

EFFECTS OF ULTRASONIC NOISE ON HEARING

Ultrasounds of 12–16 kHz masking bone-conduction caused an increase in the hearing threshold by 15–22 dB. Furthermore, masking curves for noise of middle frequencies (26 and 39 kHz) resembled an average audiogram of people with hearing deficiencies caused by years of exposure to ultrasonic noise

Fujimoto K. et al. 2005

Ultrasound exposure is a significant predictor of hearing loss, primarily at high frequencies between 10 and 14 kHz. In contrast, exposure to industrial noise in the audible range resulted in hearing loss at conventional frequencies

Maccà I. et al. 2015

Exposure to audible high-frequency sounds and ultrasonic signals exceeding the hearing range may increase the risk of hearing damage as a result of an overlap of stimuli originating from both these signals in the inner ear

Lenhardt M.L. 2003

EFFECTS OF ULTRASONIC NOISE ON HEARING

Workers exposed to ultrasonic noise and audible noise had worse hearing status than workers exposed exclusively to audible noise of similar A-weighted sound pressure levels. The study found that audiometric hearing thresholds in the frequency range of 8-12 kHz were higher (worse) in the group of employees exposed to noise generated by low-frequency ultrasonic welding devices

Dudarewicz A. et al. 2017

The results consistently indicated worse hearing among the ultrasonic device operators as compared to the control group. Both extended high-frequency audiometry **EHFA** and distortion-product otoacoustic emissions **DPOAE** seem to be useful tools for recognizing early signs of hearing loss among ultrasonic device operators. The study concludes that ultrasonic device operators are at risk of hearing impairment

Dudarewicz A. et al. 2022

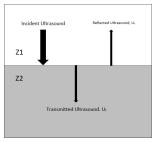
No evidence that ultrasound exposure at the levels, frequencies, and durations used in the study (**40 kHz tones at 105, 110, 115, and 120 dB** SPL for 10 minutes at each level) had any temporary or permanent effects on hearing function as assessed by several psychophysical and electrophysiological measures. Specifically, there were no significant differences between the exposure group and the control group in terms of changes in audiometric thresholds or speech-in-noise understanding

Lenhardt M.L. 2003

THERMAL EFFECTS

A mouse dies from overheating after 10 s to 3 min of exposure to a signal of 20 kHz and level of 160 dB

Allen C.H. et al. 1948



A lethal level for signals of 18–20 kHz for an unshaven mouse were 144 dB and for a shaven mouse 155 dB

Danner P.A. et 1954

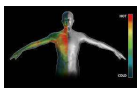
The mismatch of acoustic impedance between the air and human skin tissue prevents, at considerable extent, penetration of ultrasonic energy in the human body and, therefore, only relatively high intensities of ultrasonic waves can be dangerous for the human body.

Acton W.I. 1974

THERMAL EFFECTS

Ultrasounds at level of 159 dB may cause moderate warming of the surface of the human body - according to computational simulations, exposure to ultrasounds for ~50 min at level of at least 180 dB may be fatal 13

Nepplras E.A.1980



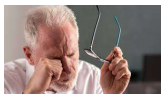
After a day of working with ultrasonic devices, body temperature of 40% of studied workers increased by 0.5 °C and in some cases even by 1–2 °C 9

Acton W.I. 1974

Cases of burns on the hand skin between fingers from accidental exposure to a signal with a frequency of 20 kHz and level of 165 dB 10

Acton W.I. 1974

SUBJECTIVE SYMPTOMS



Appearance of subjective symptoms of exposure to noise emitted by ultrasonic devices like **dizziness, balance disturbances, tinnitus and fatigue**. It is assumed that those symptoms result from the effect of noise on the vestibular system; however, further studies are necessary

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Sounds with frequencies over ~17 kHz and level exceeding 70 dB may cause negative symptoms among exposed workers such as excessive fatigue, nausea, ear fullness and headache

24

"Audible" components of the noise spectrum are, above all, responsible for subjective symptoms among workers exposed to noise emitted by ultrasonic devices.

9

SUBJECTIVE SYMPTOMS

Operators of ultrasonic welding machines subjectively assessed acoustic conditions at workstations, complaints and sensations related to noise at the workplace, and self assessed their hearing and health. About 29.4% of the workers did not report any complaints related to noise at the workstations

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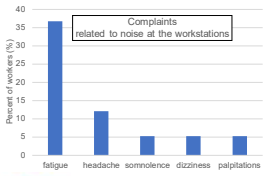

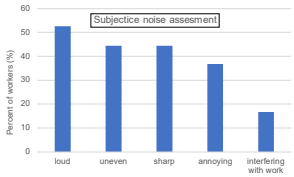

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12

EFFECTS ON FUNCTIONAL CHANGES

Exposure to sounds with a frequency of 21 kHz and level of 110 dB for 3 h daily for 10–15 days caused functional changes in the cardiovascular and central nervous systems

35

Workers exposed to noise emitted by ultrasound devices suffered from increased neural excitability, irritation, memory problems and difficulties with concentration and learning

34

Levels of 90–110 dB within the range of lower frequencies (21 kHz) and 110–115 dB within the range of higher frequencies (40 kHz) constituted the limit of occurrence of functional changes

36

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13

SUMMARY

- **Hearing loss**: Some conflicting results and the absence of consistent findings indicate the need for further comprehensive investigations in this area to better understand the effects of ultrasound on hearing.
  Because audible noise is also present in industrial conditions, it is difficult to interpret the results of environmental studies on the effects of ultrasounds on hearing
- **Thermal effects:** Ultrasound exposure can lead to both thermal and non-thermal effects on tissues, and the extent of damage depends on various factors such as temperature, exposure time, and type of ultrasound used
- **Subjective symptoms:** Symptoms like headache and dizziness, tinnitus, balance disturbances and nausea are typical for workers exposed to ultrasounds of low frequencies. It is assumed that those symptoms result from the effect of noise on the vestibular system; however, further studies are necessary
- **Functional changes:** Workers using ultrasonic devices suffered from functional changes such as neurastenia, cardiac neurosis, hypotension, heart rhythm disturbances and adrenergic system disturbances

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14

CONCLUSIONS

The establishment of TLVs for occupational exposure to ultrasonic noise has been vital to protect workers' health. However, the lack of specific limits for each outcome and the absence of a consistent method for measuring ultrasonic noise exposure demonstrate that existing safety measures may be insufficient. Therefore, it's important to adapt existing measurement methods and develop new strategies for reliably quantifying ultrasound exposure.

In conclusion, the effects of ultrasound exposure are considerable but variable. Despite raising concerns over potential adverse effects from airborne ultrasound over 70 years ago, further research is needed to comprehensively understand the nature of these effects and to develop effective measures for monitoring and mitigating ultrasound exposure in occupational settings.

This presentation was created and published on the basis of results of a research task carried out within the scope of the 6th stage of the National Programme "Governmental Programme for Improvement of Safety and Working Conditions", funded by state services of the Ministry of Family, Labour and Social Policy (under the name of the Ministry of Family and Social Policy prior to December 12th, 2023).
Task no. 3.25.01 entitled "Revision of permissible ultrasonic noise values in the workplace".
The Central Institute for Labour Protection – National Research Institute is the Programme's main co-ordinator.

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15

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THANK YOU FOR YOUR ATTENTION

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